Evaluation of the contact switch materials in high voltage power supply for generate of underwater shockwave by electrical discharge

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ABSTRACT
We have developed the high voltage power-supply unit by Cockcroft-Walton circuit for ingenerate high pressure due to underwater shockwave by electrical discharge. This high voltage power supply has the problem of the metal contact switch operation that contact switch stop by melting and bonding due to electrical spark. We have studied the evaluation of materials of contact switch for the reducing electrical energy loss and the problem of contact switch operation. In this research, measurement of discharge voltage and high pressure due to underwater shockwave was carried out using the contact switch made of different materials as brass plate, brass-carbon plate-brass and carbon block. The contact switch made of carbon is effective to reduce energy loss and problem of contactor switch operation.

Keywords: Underwater shockwave, High voltage power supply

1. INTRODUCTION

Technology of food processing of rice flower using underwater shockwave is attractive for production of new food in Japan. We have developed the high voltage power supply generating high pressure due to underwater shockwave by discharge and electrical sparking as show in Fig. 1. This high voltage power supply has the problem of the metal contact switch operation that contact switch stop by melting and bonding due to electrical spark [1]. The both electrode metals metal contact switch has been bonded due to electrical sparking by high voltage and current, the electrode did not operate in switching. We have studied the evaluation of materials of contact switch for the reducing electrical energy loss and the problem of contactor switch operation as shown in Fig. 2. Measurement of discharge voltage and high pressure due to underwater shockwave was carried out using the contact switch made of different materials. The materials of contact switches are brass plate only use (Fig. 2a), (Fig. 2b) and carbon block only use (Fig. 2c). As evaluation of the contact switch made of brass plate only use (Fig. 2a), the unstable discharge and variation of pressure occurs because of the roughness of the brass plate surface due to electric sparking and melting of contact. As the contact switch made of brass plate-carbon plate-brass plate (Fig. 2 b) has the electrical energy loss due to the roughness of the brass plate surface due to sparking and melting of brass-plate contact of double side of carbon plate. As the contact switch made of

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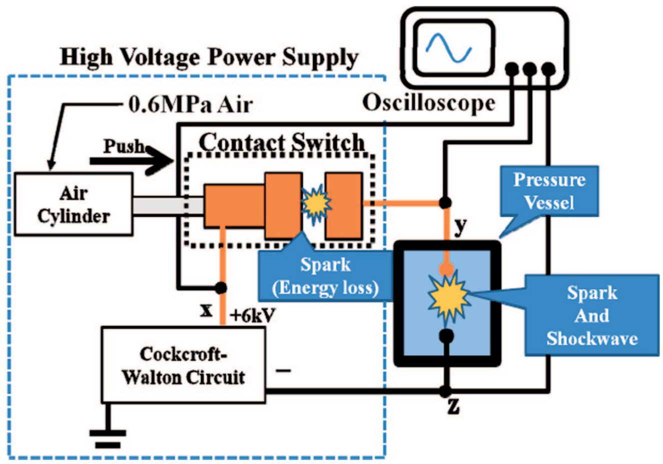

Figure 1: Diagrammatic illustration of underwater shockwave generator

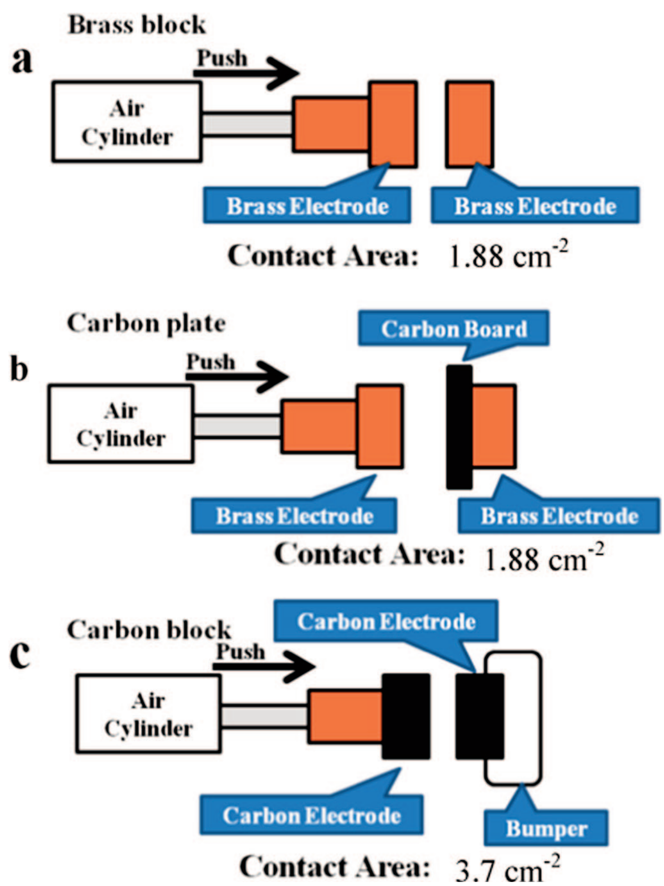

Figure 2: Diagrammatic illustration of contact switches, a: brass plate only use, b: brass plate-carbon plate-brass plate, c: carbon block only use

the carbon block (Fig. 2c), the stable discharge and high pressure occurs because of Carbon electrode can be kept to a flat surface in the discharge, and has the high wear-resistance. We have verified that the contact switch made of carbon block reduce the electrical energy loss and the melting of metal plates of the contact switch, is effective solve problem of contactor switch operation. As a result that Carbon block is suitable for material of contact switch in the high voltage power-supply unit for high pressure due to underwater shockwave by electrical discharging and sparking [1]–[3].

In this report, reveal a change in pressure when using the contactor switch as shown in Fig. 2. Furthermore, and a simple pressure measurement method has been proposed.

2. EXPERIMENTAL RESULTS

Simple measurement of pressure of underwater shockwave using by three types of contact switches as shown in Fig. 2 was carried out. Experimental condition of measurement of pressure by shockwave was shown in table 1. Cockcroft-Walton circuit (522 μF) was used for generating of charged voltage of 3.5 – 4.5 kV. Experimentation for evaluate to pressure of shockwave was shown in Fig. 3. The aluminum plate is placed in a pressure vessel (Fig. 3 a, b). An aluminum plate is deformed by the pressure caused by the discharge (Fig. 3c). For measurement of pressure of underwater shockwave, the volume of deformation to the dent of aluminum plate due to high pressure by underwater shockwave was carried out. The size of an aluminum plate (A1050P) is diameter 45 mm, thickness 0.8 mm. Aluminum plate was performed annealing at 400 °C for 60 minutes.

Figure 4 shows volume of deformed aluminum plate that deformed by underwater shockwave. The volume of deformed aluminum plate increased by increasing discharged voltage. This result shows that higher pressure shockwave by charged voltage 3 – 4.5 kV was generated by contact switch made of carbon plate (Fig. 2, c). Discharged energy in pressure vessel at charged energy about 5.3 kJ (4.5 kV, 522 μF) were about 100 MW as contact switch made of carbon block, about 88 MW as Blass plate, about 63 MW as Blass plate - Carbon plate - Blass plate [1]–[3]. Discharged energy as contact switch made of carbon block was higher than another material as Blass plate and Blass plate - Carbon plate - Blass plate. Therefore, volume of deformed aluminum plate as contact switch made of carbon plate was larger than another material.

The estimation of the pressure of the dent of aluminum plate as shown in Fig. 4 was carried out. Pressure measurements using the pressure sensitive sheet (FUJIFILM, PRESCALE Medium PS) was carried out. Figure 5 was shown that the pressure sensitive sheet was discolored red to be strong pressure. The strong pressure has changed the red color to the strong red color. Observation of the changing of color of the pressure sensitive sheet by pressure of underwater shockwave was carried out. Experimental conditions were shown at Table 2. Cockcroft-Walton circuit (392 μF) was used for generating of charged voltage of 4 – 6 kV. Contact switch made of carbon block as shown in Fig. 2, c was used at this observation.

Table 1: Experimental condition of measurement of pressure by shockwave

High voltage generator	**Total capacitance**	**Charged voltage [kV]**	**Electrode to aluminum clearance [mm]**
18steps Cockcroft-Walton circuit	522 μF	3.5, 4.0, 4.5	75

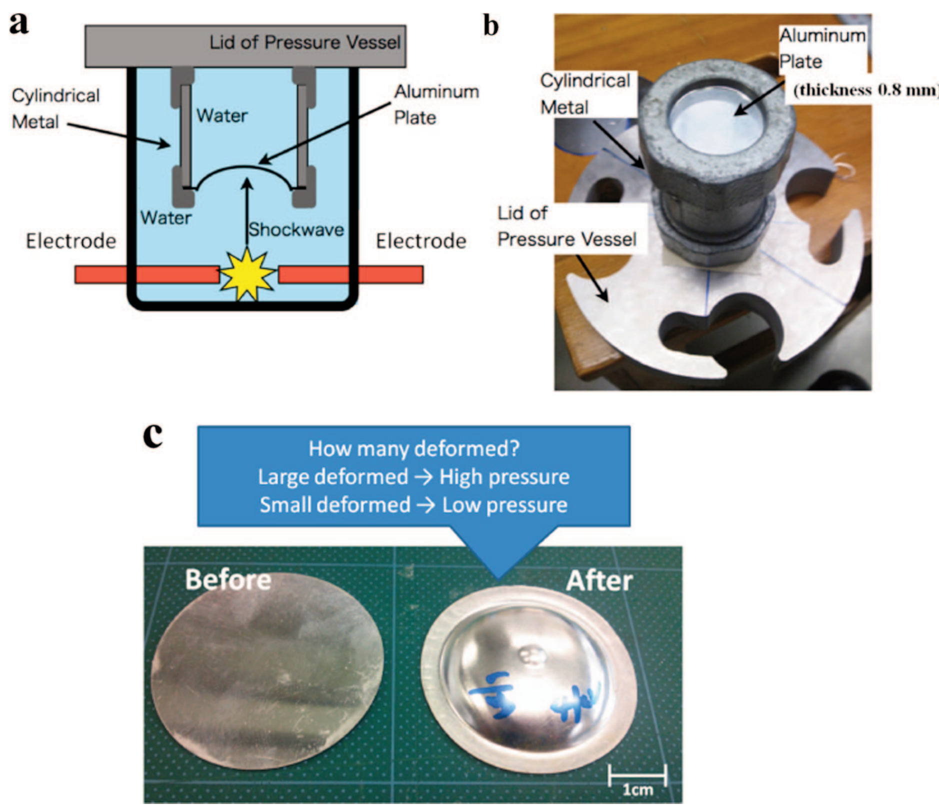

Figure 3: a: Diagrammatic illustration of a cross section of pressure vessel b: Cylindrical metal fixed to the lid, c: Before and after deformation of aluminum plate (charged voltage 4kV, 522 μF)

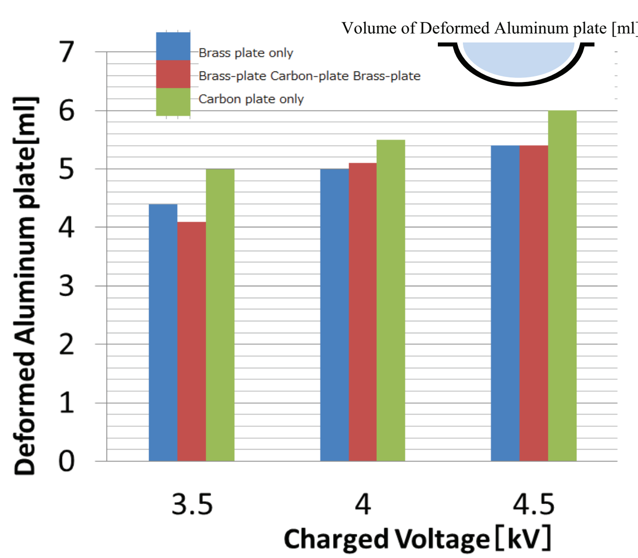

Figure 4: Volume of deformed aluminum plate by shockwave

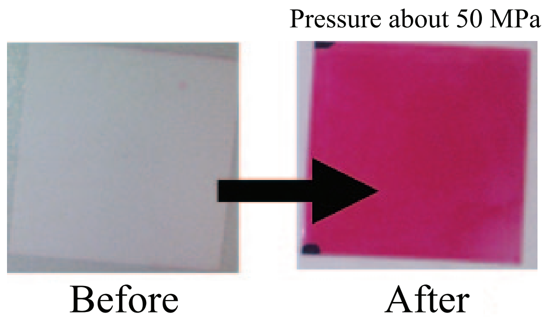

Figure 5: Discoloration of pressure sensitive sheet (FUJIFILM, PRESCALE Medium PS)

Table 2: Experimental condition of measurement of pressure by pressure sensitive sheet

High voltage generator	Total capacitance	Charged voltage [kV]	Electrode to aluminum clearance [mm]
24steps Cockcroft-Walton circuit	392 μF	4.0, 5.0, 6.0	75

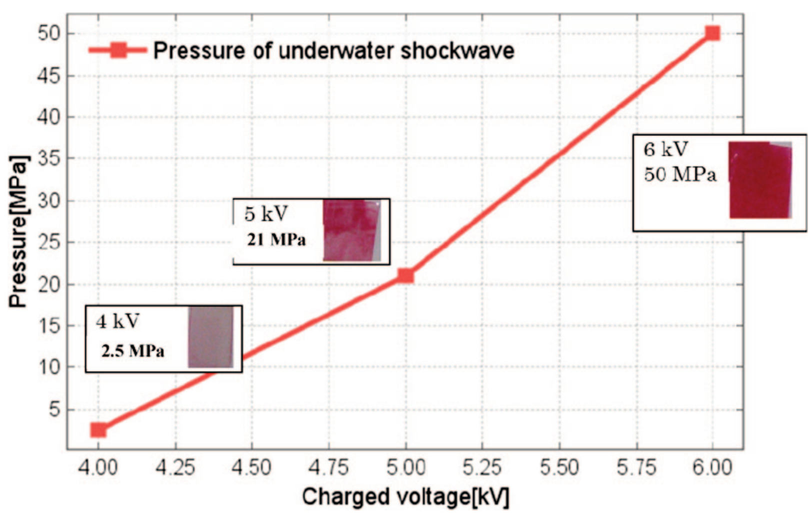

Figure 6: Relationship between charged energy and pressure of Cockcroft-Walton circuit (392 μF)

Figure 6 shows relation of charged energy and pressure by shockwave that generated by Cockcroft-Walton circuit (392 μF). The red color of the pressure sensitive sheet became dark with increasing charging voltage. The pressure of underwater shockwave was about 50 MPa at charged voltage 6 kV, about 21 MPa at 5.0 kV, about 2 MPa at 4.0 kV. Measured pressure was also increased with the increase of charged energy. The color of the recording paper has been darkened by the pressure increase due to the charging voltage increase.

Configuration of circuits of the power supply in experiment as shown in Fig. 4 and Fig. 6 was different (Cockcroft-Walton circuit. 522 μF and 392 μF). Comparison of the relationship of discharged energy and charged energy of the two power sources was carried out. Figure 7 shows comparison of the relationship of discharged energy and charged energy by Cockcroft-Walton circuit (522 μF) and circuit (392 μF). Calculation of the charged energy was carried out using the capacitance of each circuits and the charged voltage. Calculation of discharged energy was carried out using the measured current value by the Rogowski coil probe and the voltage measured by the high-voltage probe. In this experiment, contact switch was made of carbon block as shown in Fig. 2, c.

Relationship of discharged energy and charged energy are overlapped in the Cockcroft-Walton circuit of 522 μF and 392 μF. This result shows that two Cockcroft-Walton circuits can be the same evaluation when compared with discharged energy and charged energy.

Figure 8 was redrawn to discharge energy of the horizontal axis of Fig. 7. Discharged energy of Cockcroft-Walton circuit (522 μF) was drawn on the approximate line of discharged energy vs. pressure of underwater shockwave of circuit (392 μF). Pressure has been estimated in points of the approximate line. Pressure was estimated about 50 MPa at 4.5 kV (522 μF), about 15 MPa at 4.0 kV, about 2.5 MPa at 3.5 kV.

Figure 9 shows estimated pressure vs. volume of deformed aluminum plate (in Fig. 4) using contact switch made of carbon block as shown in Fig. 2, c. From Fig. 9, pressure was predicted 250 kPa when aluminum plate volume was 4 ml.

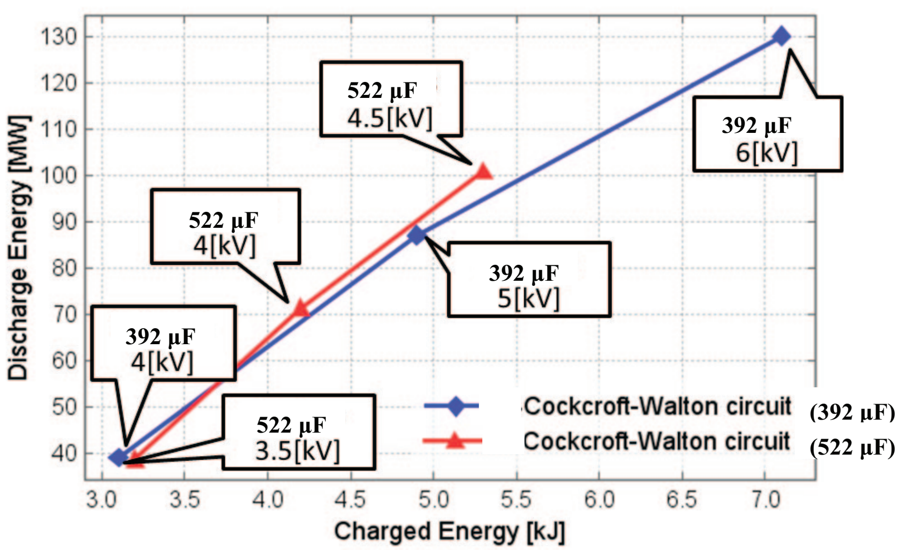

Figure 7: Relation of discharged energy between Cockcroft-Walton circuit (522 μF) and circuit (392 μF)

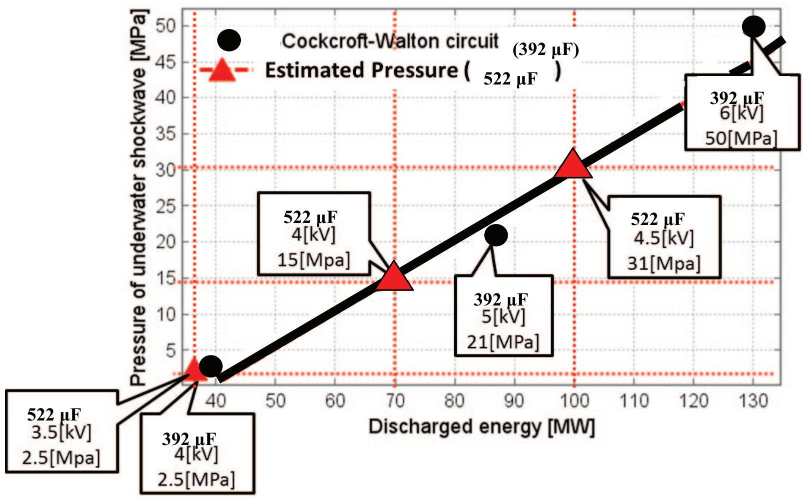

Figure 8: Relationship between charged energy and estimated pressure of shockwave by Cockcroft-Walton circuit (522 μF) on Cockcroft-Walton circuit (392 μF)

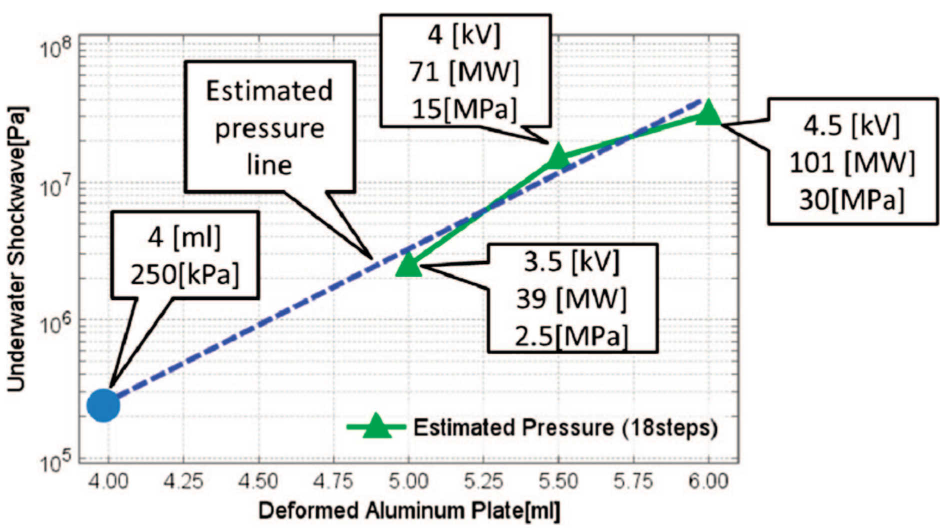

Figure 9: Relationship between deformed aluminum plate and pressure of underwater shockwave using Cockcroft-Walton circuit (522 μF) and contact switch made of carbon plate

3. CONCLUSION

In this report, reveal a change in pressure when using the contactor switch as shown in Fig. 2. Furthermore, and a simple pressure measurement method has been proposed. In the experiment of deformed of aluminum as shown in Fig. 4, volume is large deformed of aluminum when using the contact switch made of carbon block. The contact switch made of carbon block reduce the electrical energy loss and the melting of metal plates of the contact switch, is effective solve problem of contactor switch operation [1]. The pressure generated revealed an increase in the carbon block than the other materials as shown in Fig. 5.

Furthermore, a simple pressure measurement method use for deformed aluminum plate due to under water shockwave has been proposed as shown in Fig. 9. By using this method, pressure of roughly can be predicted by the volume of the deformation.

REFERENCES

[1] T. Matsui, K. Higa, R. Matsubara, S. Hanashiro, O. Higa and S. Itoh, Measurement of discharged energy and pressure of underwater shockwave changing materials of contact switch in high voltage power supply, Materials Science Forum. 2014, Vol. 767, pp. 250–255.

[2] T. Matsui, K. Higa, R. Matsubara, S. Hanashiro, O. Higa, and S. Itoh, Measurement of Discharged Energy and Pressure of Underwater Shockwave Changing Materials of Contact Switch in High Voltage Power Supply, Proceedings of ESHP2013, 2013, p. 51.

[3] R. Matsubara, T. Matsui, O. Higa, K. Higa, K. Shimojima, Y. Miyafuji, K. Naha, S. Tanaka and S. Itoh, Examination of power supply the rice powder making device with the pressure vessel having the clear window using underwater shock wave, Proceedings of ASME, 2012, PVP2012-78821.